

CLAIMS

What is claimed is:

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1. A method of phase-shifting a beam from an electromagnetic beam source in a lithographic process comprising:
 - focusing a beam from the electromagnetic beam source onto a mask, the mask adapted to selectively phase-shift at least a portion of the beam according to a predetermined pattern;
 - passing the beam from the electromagnetic beam source through the mask producing a phase-shifted beam; and
 - directing the phase-shifted beam at a substrate adapted to be selectively etched according to the predetermined pattern.
- 10 2. The method of claim 1 wherein the phase-shifted beam comprises a plurality of beam portions.
- 15 3. The method of claim 2 wherein the beam portions include at least a first beam portion and a second beam portion.
- 20 4. The method of claim 3 wherein the first beam portion corresponds to at least one primary feature and the second beam portion corresponds to at least one assist feature.
- 25 5. The method of claim 3 wherein the first beam portion and the second beam portion are at unequal phases.

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6. The method of claim 5 wherein the first beam portion is substantially a multiple of 180 degrees out of phase from the second beam portion.

7. The method of claim 1 wherein the phase-shift is a strong phase-shift.

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8. The method of claim 7 wherein the strong phase-shift substantially eliminates zero-order light between the first beam portion and the second beam portion.

9. The method of claim 7 wherein the strong phase-shift is operable to balance opposing electric fields between the first beam portion and the second beam portion.

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10. The method of claim 4 wherein the primary feature is an isolated feature on the mask.

11. The method of claim 4 further comprising forming the assist feature by a subtractive etch process.

12. The method of claim 4 further comprising forming the primary feature by a subtractive etch process.

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13. The method of claim 1 further comprising forming the mask from a photomask material having a transmittance greater than zero and less than or equal to one.

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14. The method of claim 4 further comprising forming the assist feature by an additive process.

15. The method of claim 4 further comprising forming the primary feature by an additive process.

16. The method of claim 1 wherein the electromagnetic beam source is an actinic light source.

17. The method of claim 1 further comprising the steps of:
employing an EMF (electromagnetic field) simulator; and
determining a complex transmittance and phase.

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18. The method of claim 4 wherein the at least one assist feature comprises multiple pairs of assist features.

19. The method of claim 4 wherein the at least one primary feature comprises two dimensional primary features.

20. A phase-shift mask adapted to selectively phase-shift a beam from an electromagnetic beam source comprising:

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a phase-shift mask comprising a photomask material adapted to transmit the beam as a phase-shifted beam, the mask having a plurality of portions according to a predetermined pattern,
the portions further comprising :

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at least one first shift portion adapted to transmit the beam according to the predetermined pattern, the first shift portion operable to shift the beam according to a first phase-shift to produce a first beam portion;

at least one second shift portion adapted to transmit the beam according to the predetermined pattern, the second shift portion operable to shift the beam according to a second phase-shift to produce a second beam portion.

21. The phase-shift mask of claim 20 wherein the photomask material is quartz.

22. The phase-shift mask of claim 20 wherein the phase-shifted beam comprises a plurality of beam portions.
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23. The phase-shift mask of claim 20 wherein the first beam portion corresponds to at least one primary feature and the second beam portion corresponds to at least one assist feature.
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24. The phase-shift mask of claim 23 wherein the first beam portion and the second beam portion are at unequal phases.
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25. The phase-shift mask of claim 24 wherein the first beam portion is substantially a multiple of 180 degrees out of phase from the second beam portion.
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26. The phase-shift mask of claim 20 wherein the phase-shift is a strong phase-shift.
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27. The phase-shift mask of claim 26 wherein the strong phase-shift substantially eliminates zero-order light between the first beam portion and the second beam portion.
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28. The phase-shift mask of claim 27 wherein the strong phase-shift is operable to balance opposing electric fields between the first beam portion and the second beam portion.
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29. The phase-shift mask of claim 23 wherein the primary feature is an isolated feature on the mask.
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30. The phase-shift mask of claim 23 wherein the assist feature is formed by a subtractive etch process.

5 31. The phase-shift mask of claim 23 wherein the primary feature is formed by a subtractive etch process.

32. The phase-shift mask of claim 20 further comprising forming the mask from a photomask material having a transmittance greater than zero and less than or equal to one.

10 33. The phase-shift mask of claim 23 wherein the assist feature is formed by an additive process.

15 34. The phase-shift mask of claim 23 wherein the primary feature is formed by an additive process.

35. The phase-shift mask of claim 20 wherein the mask is operable to transmit light from an actinic light source.

20 36. The phase-shift mask of claim 23 wherein the at least one assist feature comprises multiple pairs of assist features

37. The phase-shift mask of claim 23 wherein the at least one primary feature comprises two dimensional primary features.

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